§33. Low-Frequency Instabilities Due to Flow Velocity Shear in Magnetized Plasmas

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Sheared plasma flows parallel to magnetic field lines are recognized to play an important role in generation and suppression of low frequency plasma instabilities. According to the experimental results, it is demonstrated that the ion-acoustic, ion-cyclotron, and drift-wave instabilities are excited and suppressed by the parallel flow velocity shear, where the destabilizing and stabilizing mechanisms are well explained by the kinetic theory.[1)] In the experimental investigation, however, it is difficult to change the shape and the location of the velocity shear, and the plasma parameters such as the ratio of the ion to electron temperature, which are very effective in the growth rate of the shear driven instabilities.

In this sense, a particle simulation is very useful method to clarify the effects of the velocity shear, because the simulation can easily set these parameters. From the viewpoint of investigating the general properties of the velocity shear driven instabilities, the simulation should be performed in the three dimensional (3D) system because in most cases waves propagate obliquely or perpendicularly to the direction of the flow velocity gradient under the influence of the velocity shear.

In our work, a three dimensional electrostatic particle simulation with a periodic boundary model is performed,[2)] where an external uniform magnetic field points to the positive z direction. Electrons and ions are uniformly loaded in the system at t=0. The system sizes L_x, L_y and L_z are $128\lambda_{De}$, $128\lambda_{De}$ and $512\lambda_{De}$, respectively. Here, λ_{De} is the Debye length. The number of electrons and ions per unit cell is 64. The ion to electron mass ratio m_i/m_e is fixed at 400. The ratio of the electron cyclotron to electron plasma frequency is ω_{ce}/ω_{pe} = 5 and the ion to electron temperature ratio is T_i/T_e=0.5. The time step width Δt is $0.1\omega_{pe}^{-1}$. The parallel ion flow velocity shear is introduced by changing the ion flow velocity v_{di} spatially in the x direction as shown in Fig. 1, where v_{te} is the electron thermal speed. The strength of the velocity shear is changed by varying a spatial gradient of the ion flow velocity in the shear region (from the profile A to B) or the velocity deference between the central and peripheral regions (from the profile B to C).

Figure 2 shows time evolutions of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the ion density fluctuation $\tilde{n}_i/\bar{n}_i$ as a function of the velocity shear strength, which is determined by the profiles of the ion flow velocity shown in Fig. 1. These modes are measured in the velocity shear region (32 < x/λ_{De} < 36), which is indicated by dotted lines in Fig. 1.

According to the frequency spectra of these modes, the observed waves are identified as an obliquely propagating ion-acoustic instability. The fluctuation amplitude is found to increase with increasing the shear strength (A→B), but the instability is gradually stabilized when the shear strength exceeds a critical value (B→C), which is consistent with the experimentally obtained results.[1)]

In addition, these results clarify that the instability is characterized by the velocity shear strength independently of the velocity profile which is determined by the variation of the spatial velocity gradient or the velocity deference.

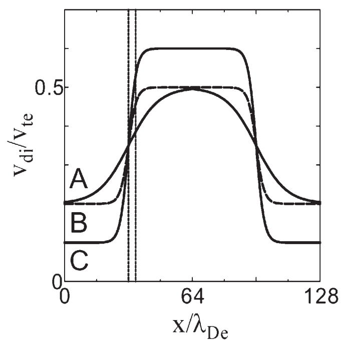

Fig. 1. Profile of ion flow velocity v_{di} in the x direction.

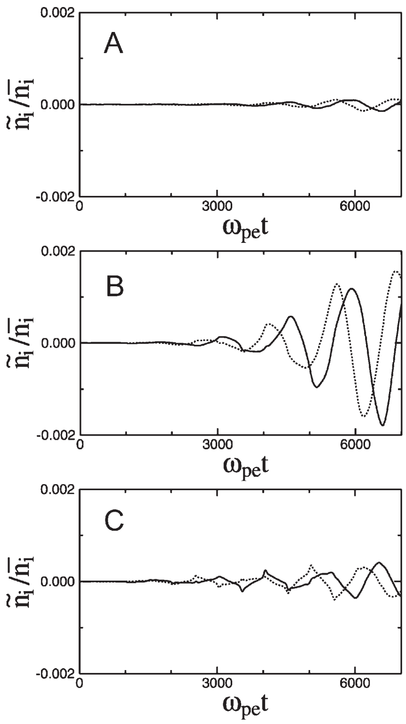

Fig. 2. Time evolutions of the real (solid line) and the imaginary (dashed line) parts of the spatial Fourier mode of the ion density fluctuation $\tilde{n}_i/\bar{n}_i$ as a function of the velocity shear strength.

Reference
1) Kaneko, T. *et al.* : Phys. Rev. Lett. **90** (2003) 125001.
2) Matsumoto, N. *et al.* : J. Plasma Fusion Res. SERIES, **6** (2004) 707.